CASE STUDY OF SHORT-TERM ELECTRICITY LOAD FORECASTING WITH TEMPERATURE DEPENDENCY

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Control and Instrumentation)"

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ABSTRACT

Load forecasting is very essential to the operation of electricity companies. It enhances the energy-efficient and reliable operation of a power system. This is a case study of short-term load forecasting using Artificial Neural Networks (ANNs). This load forecasting program gives load forecasts half an hour in advance. Historical load data obtained from the electricity generation company will be use. The main stages are the pre-processing of the data sets, network training, and forecasting. The inputs used for the neural network are one set of historical load demand data and five sets of temperature data. The neural network used has 3 layers: an input, a hidden, and an output layer. The input layer has 5 neurons, the number of hidden layer neurons can be varied for the different performance of the network, while the output layer has a single neuron.

ABSTRAK

System yang dapat menganggarkan keperluan kuasa elektrik untuk kegunaan harian merupakan ciri yang penting untuk sesebuah syarikat yang menghasilkan kuasa elektrik. System tersebut dapat membekalkan kuasa elektrik secara berterusan tanpa menghadapi sebarang masalah. Oleh itu, kajian kes ini telah dikaji dengan menggunakan Artificial Neural Network (ANNs) bagi menghasilkan system tersebut. Kajian ini akan dapat membuat anggaran keperluan kuasa elektrik untuk setiap setengah jam. Maklumat yang digunakan bagi anggaran tersebut akan didapati daripada syarikat yang menghasilkan kuasa elektrik. Proses yang teribat dalam kajian ini terbahagi kepada tiga. Proses tersebut ialah proses mengumpul data, latihan Neural Network dan akhir sekali ialah proses anggaran kuasa elektrik. Maklumat yang digunakan ialah satu set kegunaan kuasa elektrik untuk setiap setengah jam yang lama dan lima set maklumat suhu. Neural network ini mengandungi tiga lapisan, input, hidden dan output. Lapisan input mengandungi lima neurons, untuk lapisan hidden, bilangan neurons adalah bergantung kepada pengguna dan akhir sekali ialah lapisan output yang mengandungi satu neuron.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

A reliable and continues supply of electrical energy is necessary for the functioning of today's complex societies. Due to the increasing consumption and obstruction of various kinds, and the extension of existing electrical transmission networks, power systems operated closer and closer to their limits thus the chances of occurrences overloading, equipment failures and blackout increases. Moreover, another problem to be faced is that the electrical energy cannot be stored whereby the electricity is only generated when needed. As a result from the electricity supply and demand fluctuating, an accurate model for electric power load forecasting is essential to the operation and planning of electricity generation in order to provide an effective and reliable operation.

Load forecasting predict the demand for electricity over the planning period of time for the utility in planning generation schedules in a power system where it helps on making decision on when and how much electricity need to be generated. Load forecasts

are extremely important for energy suppliers, ISOs, financial institutions, and other participants in electric energy generation, transmission, distribution, and markets. Load forecasts can be divided into three categories: short-term forecasts which are usually from one hour to one week, medium forecasts which are usually from a week to a year, and long-term forecasts which are longer than a year. However, short-term load forecasting is more accurate than medium and long term load forecasting due to the several factors.

For short-term load forecasting several factors should be considered, such as time factors, weather data, and possible customers' classes. However according to the electric load prediction survey [1] published, it indicated that of the 22 research reports considered, 13 made use of temperature only, 3 made use of temperature and humidity, 3 utilized additional weather parameters, and 3 used only load parameters which means that the most important factor that decides on the accuracy of the result of short term load forecasting is the temperature. This highlighted that temperature will directly affected the accuracy of the short term load forecast model.

In this case, Artificial Neural Network (ANN) is used to obtain the short term load forecast model with the historical load demand data and temperature as the input parameters.

1.2 Project Objective

The main objective of this project is to propose a short-term load forecasting model with high forecasting accuracy based on the historical data of load demand by using the Artificial Neural Networks (ANN). This project is very usable in enhance the energy efficiency and reliability of a power system generation plant. The proposed short-term load forecasting model is ensuring adequate electricity generation from the power system generation plant to meet the consumers' demand and thus providing effective operation. The factors that need to be concern in the proposed short-term load forecasting model are the time and the temperature factors.

This project concentrates on the using of Artificial Neural Network (ANN) in creating the short-term load forecasting model. The scope of the project involved three stages which are summarized as followed:

i. Preliminary stage
   Step 1: Data Pre-processing
   Step 2: Data Prediction
   Step 3: Data Post-processing
ii. Network training
iii. Forecasting

1.3 Thesis Outline

The thesis is orderly organized into 6 chapters and they are outlined as below:

Chapter 1 explains the important in propose a short-term load forecasting model with high forecasting accuracy based on the historical data of load demand by using the Artificial Neural Networks (ANN). It also outlines objective and scope of this project.

Chapter 2 describes the forecasting methods used in the project. It gives a brief review of the important factors that need to be considering in load forecasting. Few short-term load forecasting methods such as similar-day approach, regression methods, time series, neural network, expert system and fuzzy logic are discussed.

Chapter 3 provides description and discussion on the neural network models for time series forecast. There are three important process involved in proposing the neural network models which are preliminary stage, network training and forecasting.

Chapter 4 indicates the introduction to Fourier and Wavelet transform. For Fourier transform, short-time Fourier transform is discussed. However for Wavelet transform, it consists of continuous, discrete and non-decimated.

Chapter 5 presents neural networks in time-series forecast. It discussed about the concept of artificial neural network and how it works. In additional, it also discussed about the perceptron network.

Chapter 6 gives the overview of the proposed forecast model that summarizes all the stages involved.

Chapter 7 shows the results and simulation obtained from the project.

Lastly, Chapter 8 is used for the conclusion and recommendations.

CHAPTER 2

FORECASTING METHODS

2.1 Important Factors for Forecasts

Generally, there are two different categories of forecasting models which are the traditional models and the modern technique.

Traditional forecast model employ time series and regression analysis through the use of statistical models such as peak load models and load shape models[8][9]. An example of such models is the Autoregressive Moving Average (ARMA model). ARMA model is a tool for understanding and perhaps predicting the future values of time series data especially in statistical and signal processing. These models are mostly linear methods and have limited ability to capture non-linearity in the load time series pattern. Therefore, it is much complex to operate the traditional forecast model. For modern techniques such as neural networks, fuzzy logic, and expert systems, it is known that these technique can be use to operate the load forecast model more effectively and accurately.

Since load forecasts can be divided into three categories: short-term forecasts which are usually from one hour to one week, medium forecasts which are usually from a week to a year, and long-term forecasts which are longer than a year, therefore this means that for each of the categories, there will be the most appropriate methods to operate the forecast models. First for the medium- and long-term forecasting, the so-called end-use and econometric approach are broadly used. Whereas, a variety of methods, which include the so-called similar day approach, various regression models, time series, neural networks, statistical learning algorithms, fuzzy logic, and expert systems, have been developed for short-term forecasting.

From the research, we know that there are a large variety of mathematical methods and ideas have been used for load forecasting. When the time goes on, the development and improvements of appropriate mathematical tools will lead to the development of more accurate load forecasting techniques thus more effective forecast models can be proposed.

However, the accuracy of load forecasting depends not only on the load forecasting techniques, but it also depends on few other factors such as weather condition and class of customers at that certain areas (e.g. residential, commercial, or industrial). Among all the factors, weather plays an important role in determining the load forecast model. Weather forecasting is an important issue where it affecting the pattern of the load demands indirectly thus the data of the temperature for a long period of time need to be obtained in proposing the load forecast models.

2.2 Short-term load forecasting methods

There is variety of statistical and artificial intelligence techniques have been developed for short-term load forecasting for example similar-day approach, regression

methods, time series, expert system and fuzzy logic. Each of the methods will be discuss in detail in the next session.

2.2.1 Similar-day approach

This approach is based on searching historical data for days within one, two, or three years with similar characteristics to the forecast day. Similar characteristics include weather, day of the week, and the date. The load of a similar day is considered as a forecast. Instead of a single similar day load, the forecast can be a linear combination or regression procedure that can include several similar days. The trend coefficients can be used for similar days in the previous years.

2.2.2 Regression methods

Regression is the one of most widely used statistical techniques. For electric load forecasting regression methods are usually used to model the relationship of load consumption and other factors such as weather, day type, and customer class. Engle *et al.* [7] presented several regression models for the next day peak forecasting. Their models incorporate deterministic influences such as holidays, stochastic influences such as average loads, and exogenous influences such as weather. References [12], [16], [10], [3] describe other applications of regression models to loads forecasting.

2.2.3 Time Series

Time series can be defined as a sequential set of data measured over time, such as the hourly, daily or weekly peak load. The basic idea of forecasting is to first build a

pattern matching available data as accurate as possible, then obtains the forecasted value with respect to time using established model.

Generally, series are often described as having following characteristic [5]:

$$X(t) = T(t) + S(t) + R(t) \qquad t = \ldots -1,0,1,2,\ldots$$

Here, T(t) is the trend term, S(t) the seasonal term, and R(t) is the irregular or random component (which can be generated using Matlab command). At this moment, we do not consider the cyclic terms since these fluctuations can have a duration from two to ten years or even longer which is not applicable to short-term load forecasting.

We have such assumptions to make things a little easier for the moment:

1) The trend is a constant level;
2) The seasonal effect has period **s**, that is, it repeats after **s** time periods. Or the sum of the seasonal components over a complete cycle or period is zero.

$$\sum_{j=1}^{s} S(t+j) = 0$$

2.2.4 Neural Network

The use of artificial neural networks (ANN or simply NN) has been a widely studied electric load forecasting technique since 1990 [15]. Neural networks are essentially non-linear circuits that have the demonstrated capability to do non-linear curve fitting. Artificial Neural Networks are mathematical tools originally inspired by the way human brain process information. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation.

In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. In more practical terms neural networks are non-linear statistical data modeling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data. The outputs of an artificial neural network are some linear or nonlinear mathematical function of its inputs. The inputs may be the outputs of other network elements as well as actual network inputs. In practice network elements are arranged in a relatively small number of connected layers of elements between network inputs and outputs. Feedback paths are sometimes used. Before the use of artificial intelligence networks, the method of architecture needs to be determined.

The most popular artificial neural network architecture for electric load forecasting is back propagation. With the ability to approximate any continuous nonlinear function, the back propagation network has extraordinary forecasting abilities. Artificial neural networks can be use in conjunction with other forecasting techniques such as with regression trees, time series or fuzzy logic to perform a more accurate load forecasting.

2.2.5 Expert system

Expert system makes use of rules and procedures used by human experts in the field of interest into software that is then able to automatically make forecasts without human assistance. This means that basically Expert system forecasts the load according to rules extracted from experts' knowledge and operators' experience.

Expert system use began in the 1960’s for such applications as geological prospecting and computer design. Expert systems work best when a human expert is